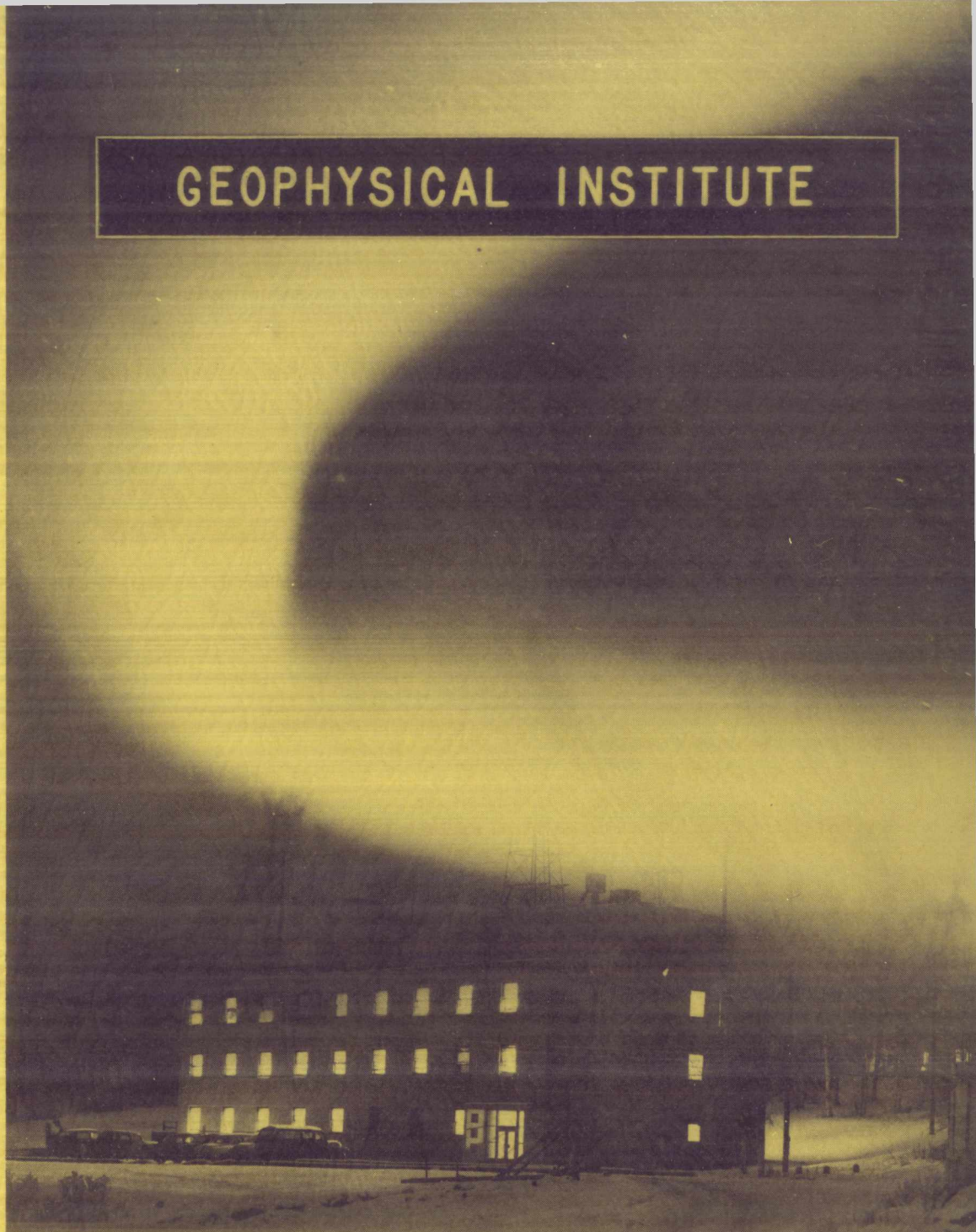


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EXPERIMENT LUXEMBOURG

Scientific Report No. 2
Contract No. AF 19(604)-3880

by

G. C. Rumi

May 1959

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GEOPHYSICS RESEARCH DIRECTORATE
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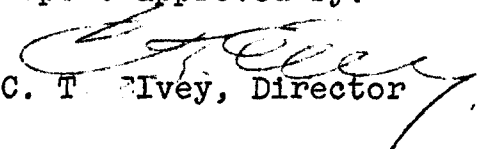

C. T. Elvey, Director

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THE D_1 , D_2 LAYERS AND THE ABSORPTION OF RADIO WAVES

1 - INTRODUCTION

The present study is concerned with the absorption of radio waves in the D region of the ionosphere. Firstly, it is shown that, if the absorbing region is split into two layers, the curve of absorption versus frequency is characterized by a point of inflection. Experimental data on absorption reported in the literature are shown to fit the theoretically derived curve. Secondly, it is shown that, if the absorbing region is composed of two layers, the f_{\min} measured with an ionospheric sounder should present a discontinuous behavior. f_{\min} plots obtained at College, Alaska are shown to behave as expected under the hypothesis of two layers in the absorbing region. These absorption data lead to conclude that the D region is composed of two layers, D_1 and D_2 .

A second section of the paper is devoted to an investigation of the electron collision frequency in the D region. The electron collision frequency is directly related to the point of inflection in the absorption versus frequency curve discussed in the first part of the paper, and to the discontinuity presented by the f_{\min} plots. Experiment Aurora data (Experiment Aurora is a plurifrequency and pluripath experiment which was carried out in Alaska from 1949 to 1955) are interpreted as an indication that the point of inflection in the absorption versus frequency curve for

a high latitude ionosphere is displaced during disturbed periods with respect to quiet periods; such a displacement is equivalent to an increase in the electron collision frequency. A similar displacement is observed in the discontinuity that affects f_{\min} plots at College, Alaska, when quiet period and disturbed period data are compared. It is deduced that the electron collision frequency in the D region increases during disturbed periods at auroral latitudes.

2 - PRESENT THEORY ON ABSORPTION

The present theory on absorption of radio waves in the ionosphere was laid down by Appleton (1932 and 1937), Booker (1935), and Farmer and Ratcliffe (1935). The coefficient of absorption of a plane radio wave passing through an ionized medium is

$$K = \frac{5.3 \times 10^{-6}}{\mu} \cdot \frac{N \nu}{\nu^2 + (\omega \mp \omega_L)^2}, \text{ with } E = E_0 e^{-\int K ds} \quad (1)$$

where K = absorption coefficient

μ = index of refraction

N = electron density

ν = electron collision frequency

ω = operating angular frequency

ω_L = longitudinal component of gyromagnetic angular frequency

E = amplitude of the absorbed wave

E_0 = amplitude of the wave before absorption

The sign + holds for the ordinary component of the radio wave and the sign - holds for the extraordinary component. The system used is the MKS.

Two different types of absorption are possible according to the conditions $\mu \sim 0$ and $\mu \sim 1$. In the first case

$$K = 60 \pi \nu \left(\frac{1}{\mu} - \mu \right) \quad (2)$$

In the second case

$$K = 5.3 \times 10^{-6} \times \frac{N \nu}{\nu^2 + (\omega + \omega_L)^2} \quad (3)$$

The type of absorption corresponding to (2) is called the deviative absorption; in fact it takes place when $\mu \sim 0$, where refraction is very strong. The type of absorption corresponding to (3) is called non-deviative and it is due to the combined action of ν and N in a given region. We will concentrate our attention on the non-deviative absorption, henceforth called briefly absorption.

The absorption of radio waves takes place mainly in the D region of the ionosphere, as indicated by Mitra and Shain (1954), where according to Chapman and Little (1957) the distribution of ν versus height h is of the type shown in Figure 1. The same Figure 1 can be interpreted as a diagram of critical height

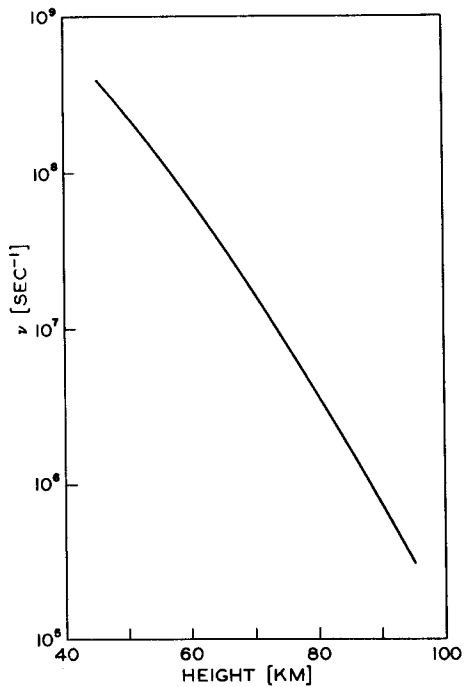


Fig. 1. Electron Collision Frequency Versus Height.

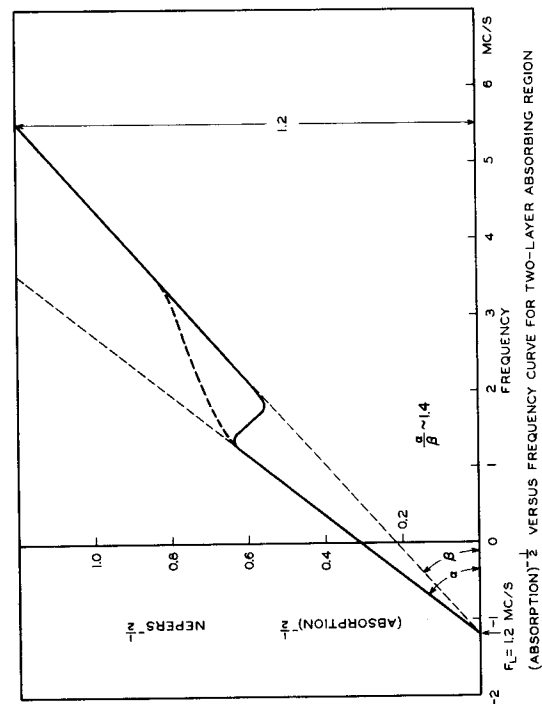


Fig. 2.

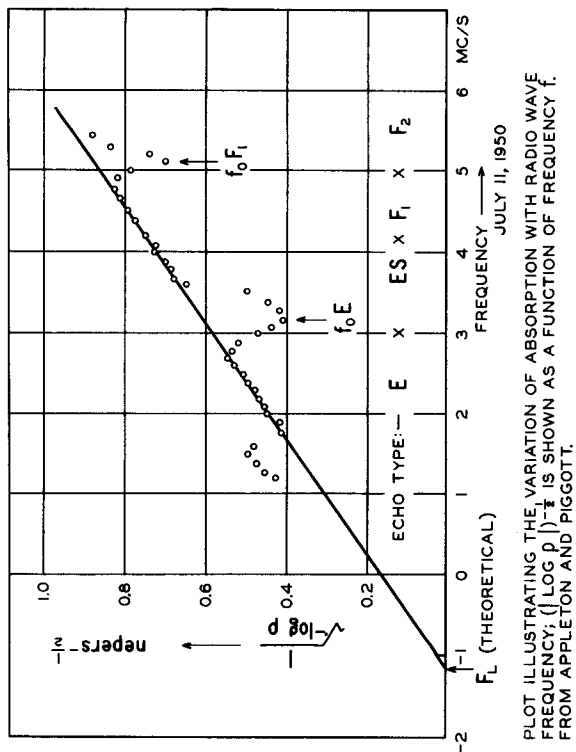


Fig. 3.

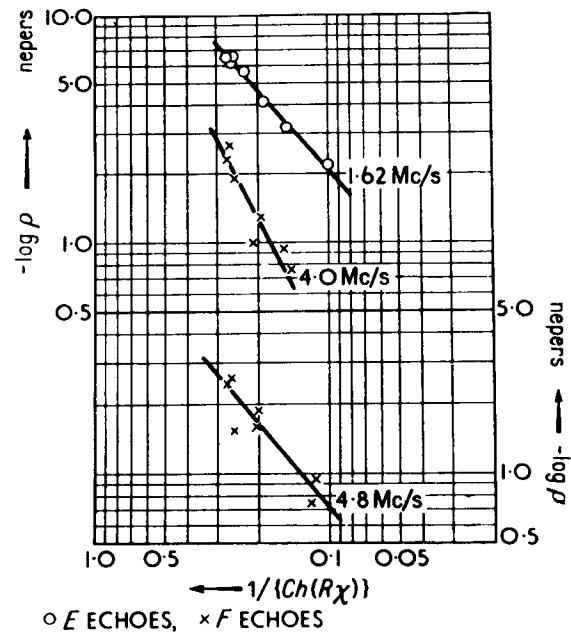


Fig. 4. Logarithmic Plots of $|\log p|$ and $1/Ch(R, \chi)$ for 1.6, 4.0, and 4.8 Mc/s on Dec. 10, 17, 1948. From Appleton and Piggott.

versus operating frequency, the critical height being defined by the condition $\nu = (\omega \mp \omega_L)$. The concept of critical height helps to introduce a simplification in (3). For the region significantly above the critical height we can write instead of (3)

$$K \sim \text{constant} \times \frac{N \nu}{(\omega \mp \omega_L)^2} \quad (4)$$

For the region significantly below the critical height we have

$$K \sim \text{constant} \times \frac{N}{\nu} \quad (5)$$

In general, the expression (4) is considered representative of the situation in the D region (see Appleton and Piggott - 1954).

A large amount of data containing information about absorption is available. One deduces that there is a good correlation between sunspot number and absorption, i.e. at the sunspot maximum the absorption is maximum (Appleton and Piggott - 1954); that a pronounced seasonal variation affects ionospheric absorption and gives rise to what has been called "the winter anomaly"; and that a maximum of absorption appears at noon or shortly afterwards.

A mechanism able to explain a few aspects of the trends indicated above has been proposed (see Appleton - 1937, and Appleton and Piggott - 1954). It is based upon two hypotheses: a) the absorbing layer obeys (4); and b) the absorbing layer is a Chapman

layer produced by photoionization. As a consequence one finds that the absorption should vary during the day according to a $\cos \chi$ law - χ being the zenith distance of the sun. Appleton and Piggott (1954) deduced that $\cos \chi$ to the first power is the correct law to use.

3 - TWO LAYER ABSORBING REGION

In this section we show what kind of relation between absorption and radio wave frequency has to be expected should the absorbing region be split into two layers.

The idea that the D region is divided in two strata is consistent with the experimental data published in recent years. Gardner and Pawsey (1953) and Bracewell and Bain (1952) deduced from experiments based upon reflection of radio waves that D_1 and D_2 layers are present in the lower ionosphere; the first one at an altitude of about 70 kilometers, and the second at about 90 kilometers.

To simplify our investigation we suppose that D_1 is a layer 5 kilometers thick centered around 65 kilometers, and D_2 is a layer 5 kilometers thick centered around 95 kilometers; of course this is a very abstract model. We attribute to D_1 a collision frequency of 3×10^7 collisions per second and to D_2 a collision frequency of 3×10^5 collisions per second (see Figure 1). The electron density in D_2 is assumed to be around 10^{11} electrons per

cubic meter, a value consistent with densities that have been measured at this height; the electron density in D_1 is taken as 10^9 electrons per cubic meter, sufficient to give a total absorption of the order of magnitude that is observed experimentally.

The calculations of the absorption that is produced by such a model lead to the plot illustrating the variation of absorption with radio frequency that is shown in Figure 2; $\left[(K_1 + K_2) s \right]^{-1/2}$ is presented as a function of the frequency; K_1 and K_2 are the absorption coefficients in D_1 and D_2 , and s is the thickness of these layers. Only the ordinary wave is considered, as it is prevalent over the extraordinary wave. We note a point of inflection between the two straight lines. The interpretation of the diagram is quite straightforward. Above 3 Mc/s the total absorption is given by

$$\frac{N_1 \nu_1 + N_2 \nu_2}{(\omega + \omega_L)^2} s \quad (6)$$

Below 3 Mc/s the total absorption is given by

$$\left(\frac{N_1}{\nu_1} + \frac{N_2 \nu_2}{(\omega + \omega_L)^2} \right) s \quad (7)$$

on account of the fact that the D_1 layer is below the critical height for 3 Mc/s.

Expression (7) can be written as

$$\frac{s N_1}{\nu_1} \quad (8)$$

under the condition that $N_1 (\omega + \omega_L)^2 \gg v_1 N_2 v_2$, or as

$$\frac{N_2 v_2 s}{(\omega + \omega_L)^2} \quad (9)$$

under the condition that $N_2 v_2 v_1 \gg N_1 (\omega + \omega_L)^2$.

Then above 3 Mc/s we have that the (total absorption)^{-1/2} versus the frequency is represented by a straight line with slope

$$\frac{1}{(N_1 v_1 s + N_2 v_2 s)^{1/2}} \quad \text{and x-intercept} = -f_L, \text{ the longitudinal}$$

component of the gyrofrequency; below let's say 1.5 Mc/s we have a straight line with slope

$$\frac{1}{(N_2 v_2 s)^{1/2}} \quad \text{and x-intercept} = -f_L.$$

The transition region characterized by a point of inflection is defined by the conditions

$$\frac{N_2}{N_1} v_2 v_1 < (\omega + \omega_L)^2 < v_1^2. \quad \text{Then the transition region is}$$

directly connected with v_1 of which it gives an indication.

The preceding discussion did not explore a detail that is worth considering. In the derivation of the plot in Figure 2 the absorption has been computed as given by K_s instead of $\int K ds$.

Now, $Ks = \int K ds$ only for N and v constant over the integration interval. But we know that at least v varies, and varies quasi exponentially; then K varies accordingly. To study how K changes with v we consider its first derivative with respect to v ; such a derivative is null when v becomes equal to $(\omega + \omega_L)$, indicating that under this condition K reaches a stationary value. Only for a stationary value of K versus v and, consequently, versus height it is to some extent correct to equate Ks to $\int K ds$. In general we should write $\int K ds = \alpha Ks$, where α is a coefficient equal to one for $v = (\omega + \omega_L)$ and decreasingly smaller than one in the neighborhood. In the present discussion we are interested in relative values and not in absolute values; we find convenient to consider $\alpha = 1$ far from the condition $v = (\omega + \omega_L)$ and then increasingly larger than one as we approach the stationary condition. That amounts to introducing the correction that is shown on the diagram of Figure 2 below the dashes of the transition region.

The correction we are speaking about is of relevant importance because it marks more strongly the point of inflection in the diagram; from this point of inflection information about the collision frequency in the D_1 layer shall be obtained.

4 - EXPERIMENTAL DATA AND TWO LAYER THEORY

Experimental data reported in the literature fit the theoretical curve discussed above. We refer to Appleton and Piggott's paper on "Ionospheric absorption measurements during a sunspot cycle" (1954), and particularly to their Figure 4, reproduced in the present paper as Figure 3. Appleton and Piggott comment the data in Figure 3 as follows: "the absorption in all cases apart from all frequencies near critical values is reconcilable in terms of the absorption of a single layer." The same authors had already pointed out that deviative absorption is usually small at vertical incidence compared with non-deviative absorption during day-time, except for frequencies near critical penetration values. The comment about Figure 3 quoted above does not take into account the kink presented by the succession of the experimental data in the proximity of 2 Mc/s. An explanation of such a kink is tentatively presented by the two authors, but they also state that the detailed examination of this particular phenomenon must await the development of a convenient technique for applying the magneto-ionic theory to the trajectories.

After what has been shown in section 3 it seems that the absorption in all cases, apart from all frequencies near critical value, is reconcilable in terms of the absorption of two layers, no further explanation being required for the kink in the proximity of 2 Mc/s; in other words we think that the experimental data of Figure 3 support the hypothesis of a two layer absorbing region.

The same paper contains supplementary information in favor of the two layer hypothesis. Reference is made to Figure 6 of Appleton and Piggott's paper, reproduced here as Figure 4. We note that on December 17, 1948, at Slough the absorption on 4.0 Mc/s was either equal or smaller than the absorption on 4.8 Mc/s. The fact that 4 Mc/s was "above but not far from noon critical frequency of the E layer" makes the situation even worse from the point of view of the one layer hypothesis. On the other hand, the two layer hypothesis does not have difficulty in explaining this apparent anomaly: the lower absorbing layer should have been located at a height where $\nu \gg 2 \pi \times (5 + 1,2) \text{ Mc/s}$, or about 60 kilometers, so that the absorption at 4.8 Mc/s could have been located at the bottom of the kink we have discussed.

5 - f_{\min} PLOTS AND TWO LAYER THEORY

Evidence for the splitting of the absorbing region into two layers is furnished by f_{\min} plots. The meaning of f_{\min} is simple: the ionospheric sounder's transmitter emits a signal at a given level, the ionospheric sounder's receiving and recording system has a given threshold, the reflecting layer has a variable height and a variable reflection coefficient; for a given reflecting layer the absorption we can allow, if we want to receive a signal just above the threshold, has a well determined value representable by a horizontal line in a $(\text{total absorption})^{-1/2}$ versus frequency

diagram; for increasing values of the electron content in the D_1 and in the D_2 layers, curves similar to the ones depicted in Figure 2 and more and more close to the frequency axis should be drawn; the intersection of the horizontal line with the flexed curve corresponding to a given electron content of the absorbing region furnishes the value of f_{\min} . When two intersections are present, f_{\min} is still uniquely defined. If the hypothesis of the two layers and therefore the dependence of absorption with frequency shown in Figure 2 are correct, we should have a very small probability for values of f_{\min} that correspond to the transition region between the two straight lines.

This probability of f_{\min} has to be considered when the changes of the reflecting screen and of the absorption with time are unknown. But information about the height of the reflecting screen is available; furthermore, the quality of its reflectivity can be derived from the knowledge of the critical frequencies and of K indexes in the sense that reflectivity will remain practically constant when these two parameters remain constant; lastly, there are occasions when the general law of variation of N with time is known. Let us think of the cases where h_E , f_E and K index are constant, and the absorption is under preponderant solar control; then we can study not only the probability distribution of f_{\min} , but also the continuity of its behavior. For example, if N and, consequentially, the absorption are known to be continually increasing, we predict, on the basis of the considerations developed in

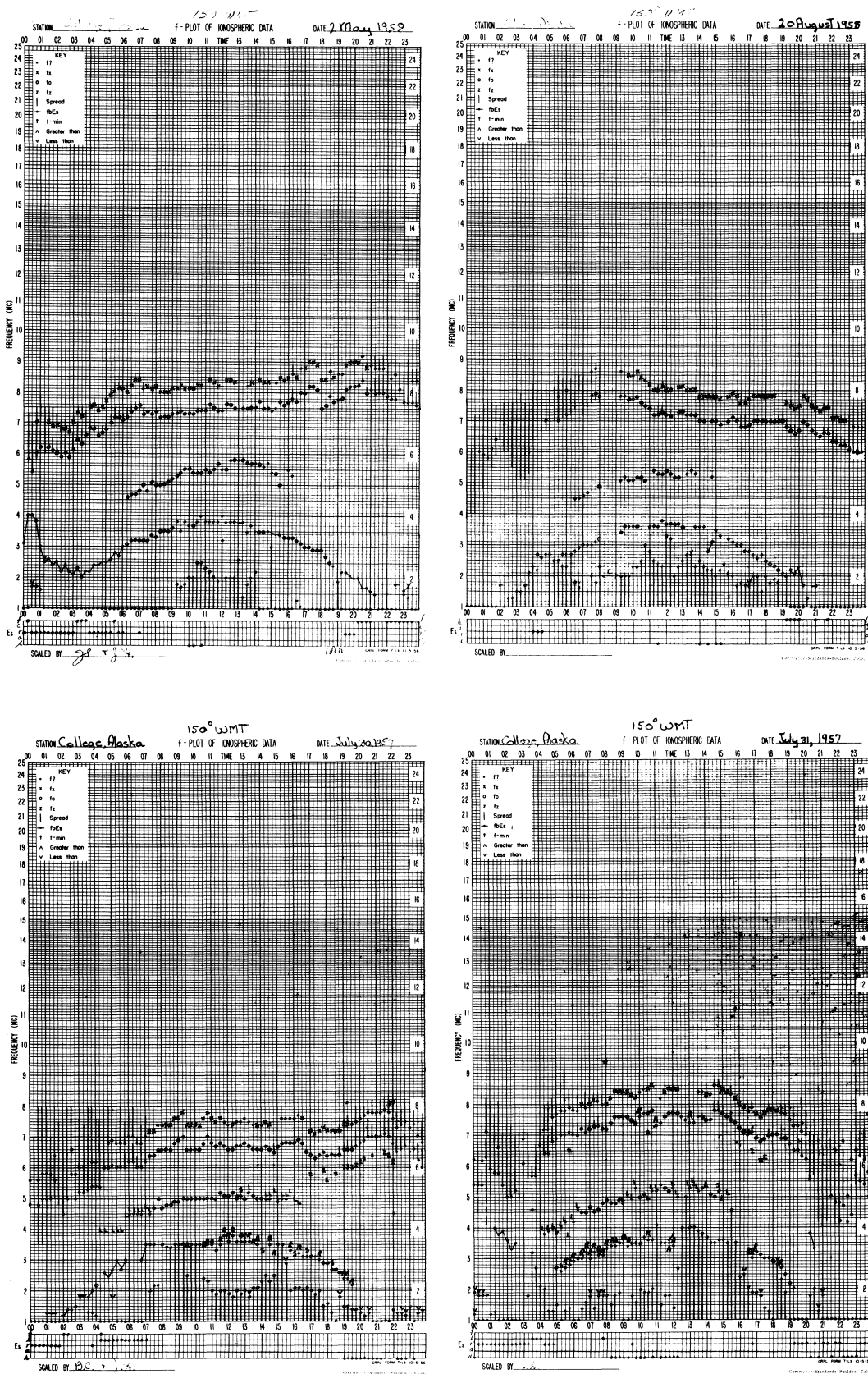


Fig. 5. May 2, 1958 - August 20, 1958 : Typical F-plots for Quiet Days.

July 30, 1957 : Quiet Day

July 31, 1957 : K Index had a Sudden Increase at Noon.

the first part of this section, that the behavior of f_{\min} will be discontinuous when the value $f_{\min} = (\nu_1 + \omega_L) / 2\pi$, ν_1 being again the collision frequency of the D_1 layer.

6 - EXAMPLES OF f_{\min} PLOTS OBTAINED AT COLLEGE, ALASKA

Typical examples of f_{\min} plots obtained at College, Alaska ($64^\circ 51.3' N - 147^\circ 49.8' W$) are presented here in Figure 5. The reader is invited to concentrate his attention on the meridian part of the plots, a time when the absorption is strongly controlled by solar activity. Comparisons between winter and summer data may be very instructive on account of the drastic difference between the two seasons at high latitudes. It is not difficult to recognize that the steplike distribution of f_{\min} predicted in accordance to a two layer absorbing region theory is present in our typical examples and that the step takes place around 3 Mc/s.

The same f_{\min} plots contain other precious information. Let us consider the example of July 30, 1957 in Figure 5. The day is quiet and normal; the solar control of the absorption is symmetrical around noon and undisturbed; the absorption increases in the early part of the morning, around 1000 begins to decrease, minimizes at noon; increases again until 1500, it decays afterward until sunset. Furthermore, let us consider the example of July 31, 1957 in Figure 5. That day an increase of K index around 1200 (AST), coincident with the step up of the f_{\min} , was recorded. Information about absorption on 27.6 Mc/s is also available.

Riometer data (courtesy of Harold Leinbach) show a rapid increase of absorption in correspondence of f_{\min} discontinuity of July 31, indicating that the riometer has enough sensitivity to follow discontinuities in absorption revealed by f_{\min} plots; the riometer signal strength on July 30 is not at all affected by a meridian decrease in absorption as shown on f_{\min} plots for the same day. Then it is deduced that, no matter how N was changing on the midday of July 30, ν has gone through a maximum: we use for 27.6 Mc/s the expression (4) and think that the expression (5) is responsible for the results recorded on July 30, 31 by the ionospheric sounder.

How could ν have increased cannot be ascertained. But one may recall the findings of Gregory (1957) and Pineo (1956). The diurnal characteristics of sky-wave delays observed during the period of October 31 to November 13, 1952, at 49.8 Mc/s over 810 km path (see Pineo) indicate that the midpoint height tends to decrease as noon is approached from about 75 to 50 km. The diurnal characteristics of 1.75 Mc/s vertical-incidence reflection heights below E-region (see Gregory) observed for period May 16-19, 1955 indicates the same trend. We will deal with this aspect of the situation again in Section 8.

7 - CONCLUSION NUMBER ONE

Experimental results described under sections 4 and 6 check the theoretical predictions presented in paragraph 3 and 5. These theoretical predictions were based upon the hypothesis of an

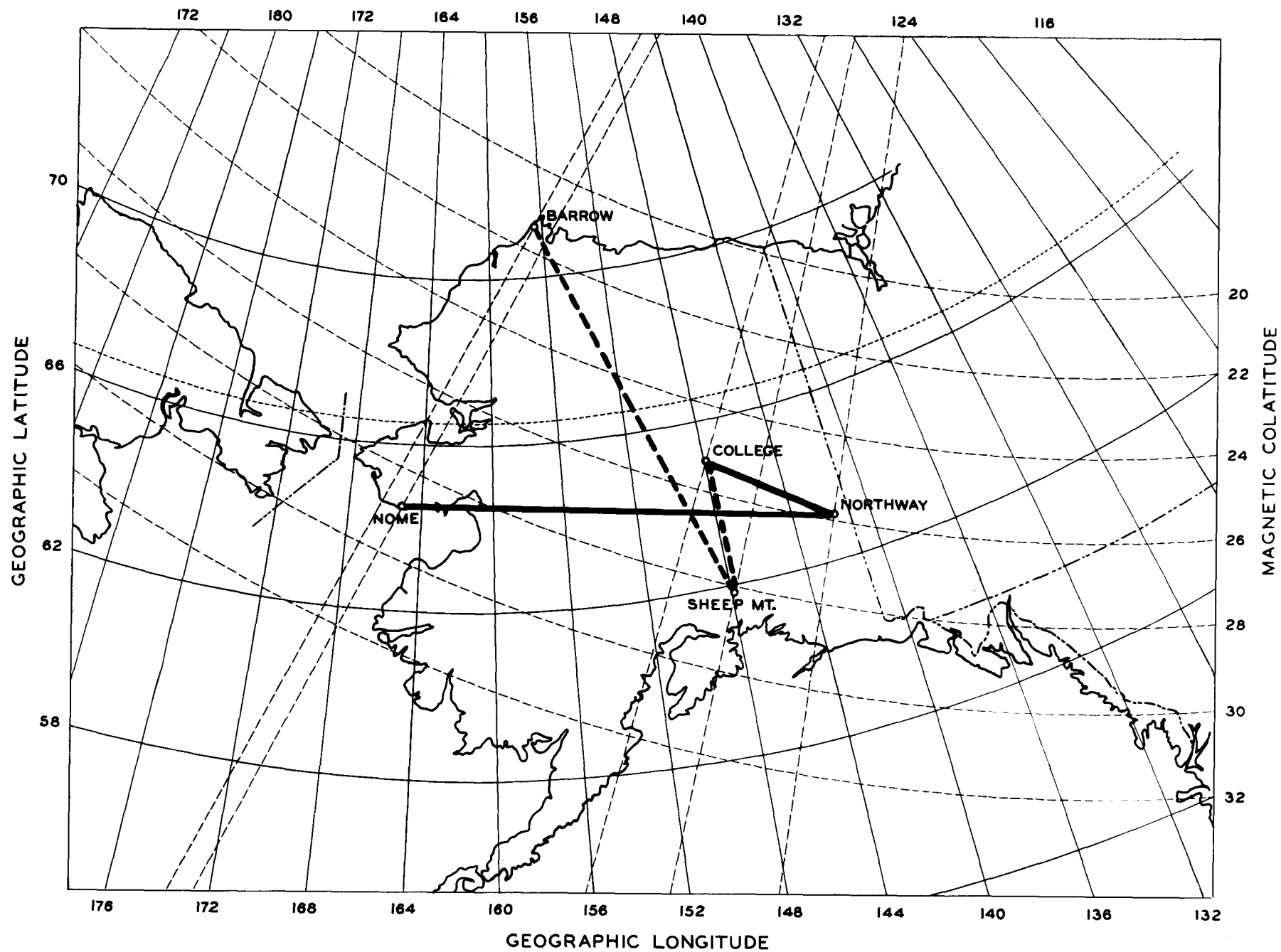


Fig. 6. Map of Experiment Aurora.

absorbing region divided into two layers. It is therefore inferred that the D region, at least where the experimental data were taken, is in general split into a D_1 and a D_2 layers.

8 - IS ν (h) CONSTANT WITH TIME ?

We start with a definition. Effective electron collision frequency is the value of ν that is constant through the absorbing layer and is equivalent, from the point of view of the resultant absorption, to the actual distribution of ν . This paragraph presents some evidence that the effective electron collision frequency in the D_1 layer increases during disturbed periods at auroral latitudes. Information on the subject is deduced from Experiment Aurora data and from f_{min} plots obtained at College, Alaska. Experiment Aurora data are interpreted as an indication that the point of inflection in the absorption versus frequency curve for a high latitude ionosphere is displaced during disturbed periods with respect to quiet periods; an analogous displacement is observed in the discontinuity that affects f_{min} plots at College, Alaska, when quiet period and disturbed period data are compared.

A) Experiment Aurora took place in Alaska from June 1949 through October 1955. The project started in 1949 when two transmitting sites and three receiving sites were established in the Territory to investigate HF radio wave propagation near the auroral zone. The map in Figure 6 illustrates the site locations,

the transmitters being at Northway and Sheep Mountain, and the receivers at College, Nome and Barrow. Thus two short path links and two long path links were in operation. Three frequencies (approximately 4, 8, and 12 Mc/s) were used at each transmitter site.

Experiment Aurora was not particularly satisfactory; its reliability from some points of view is questionable; but, as it will be explained, the use we make of such data leads to reliable conclusions.

The results of Experiment Aurora have been published in Quarterly and Final Reports by the Geophysical Institute at the University of Alaska (see Quarterly Report No. 4, 1 December 1954 to 28 February 1955 - Final Report 1 March 1955 to 29 February 1956). The diagrams we are interested in are reproduced in Figures 7 and 8. We are dealing with curves that illustrate the variation of signal strength for winter, equinoctial periods, and summer of 1954 and 1955 on the short and long paths, for three different frequencies. We concentrate our attention on the daylight hours. On 4 Mc/s short paths, in particular, we notice that the signal strength maximizes around noon in the equinoctial periods, while a dip centered around noon and spanning the daylight hours appears in the winter and summer data. On 4 Mc/s long paths and on 8 and 12 Mc/s short and long paths no antinomy of this sort appears; at least, if present, it is not so evident. We recall that the control of signal strength during daylight hours is directly connected with absorption (see Mitra and Shain - 1954).

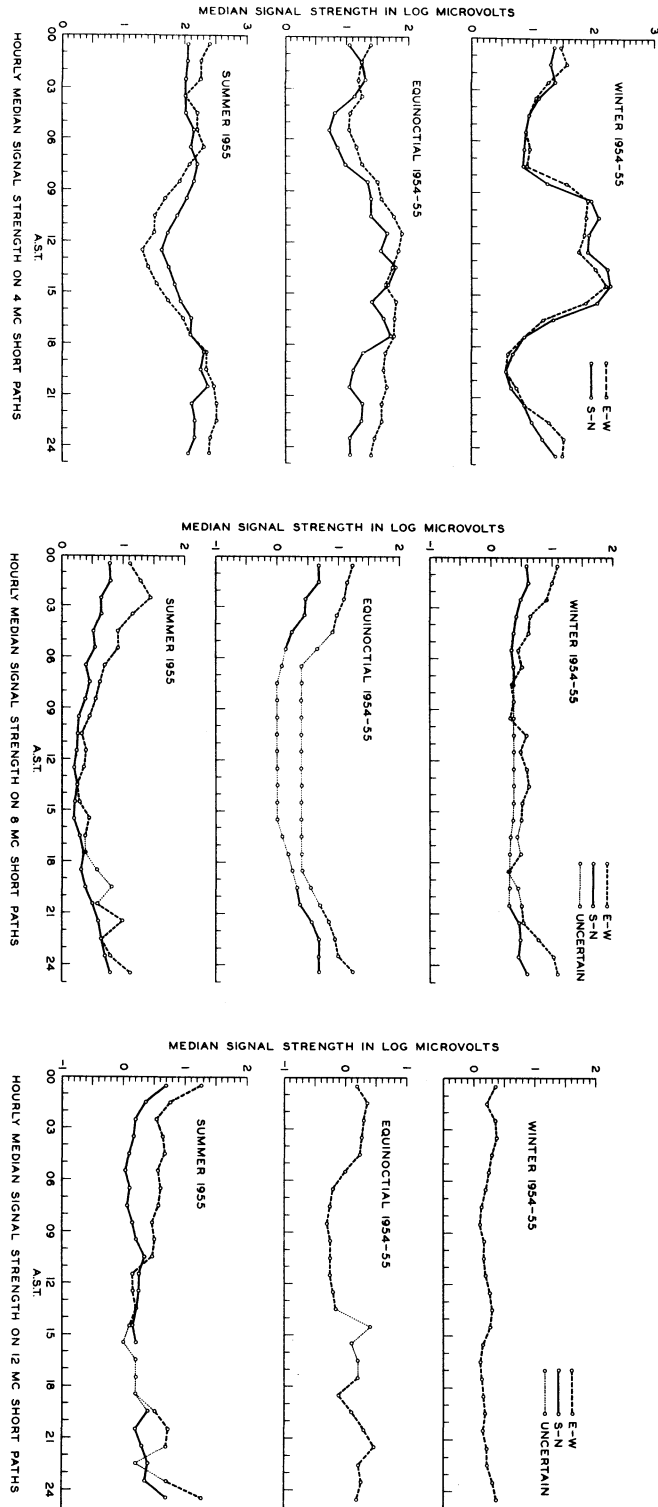


Fig. 7.

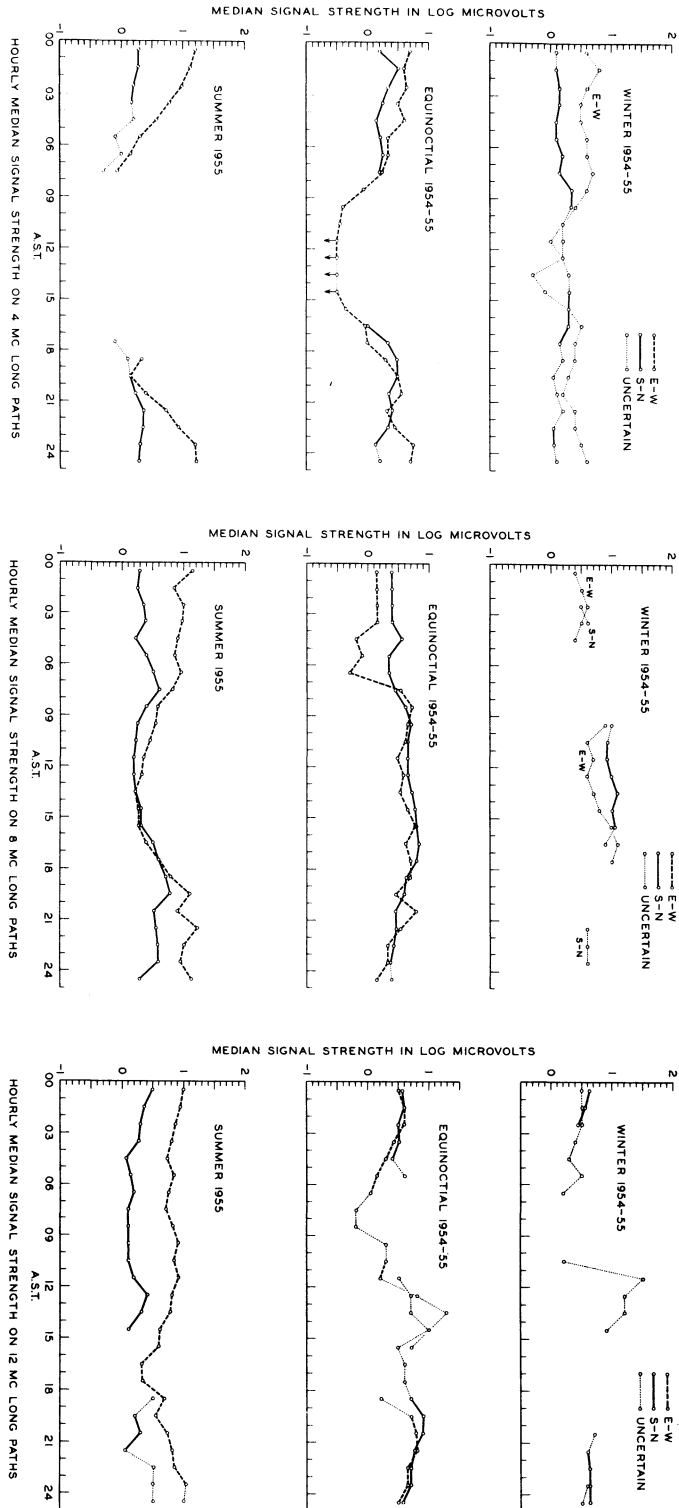


Fig. 8.

The contrast between the behavior of signal strength on 4 Mc/s and the behavior of signal strength on 8 and 12 Mc/s suggests that, at that particular time and location, the absorption on 4 Mc/s was obeying a law different from the one observed by the absorption on 8 and 12 Mc/s; we may say, after what has been described in section 2, that the absorbing layer D_1 at auroral latitudes, during periods of maximum auroral activity (spring and fall), was below the critical height for 4 Mc/s and above the critical height for 8 and 12 Mc/s. Then the absorption on 4 Mc/s was inversely proportional to ν and the absorption on 8 and 12 Mc/s directly proportional to ν . This fact together with a meridian increase of ν similar to the one we have already discussed in connection with f_{min} plots completely explains the recorded antinomy between the different frequency links.

Along the lines of the preceding interpretation the absence of any antinomy during quiet periods means that the absorbing layer D_1 is then above the critical height for 4, 8, and 12 Mc/s. Thus it follows that the effective collision frequency of the layer increases during disturbed periods with respect to quiet periods. The equinoctial seasons of the year are unquestionably labeled as disturbed periods: the numerous data collected at high latitudes do not allow any doubt about the strong influence exercised by aurorae upon ionospheric conditions in the spring

and in the fall. As far as the increase of effective collision frequency is concerned two physical possibilities are open: a) the actual collision frequency in the layer increases, or b) the height of the layer decreases. To fit these results with the results presented in the first part of this paper we could say that, according to Experiment Aurora the point of inflection in the absorption versus frequency curve, during periods characterized by strong auroral activity, is displaced horizontally toward the high frequencies.

B) Such a conclusion has to be considered valid even if the reliability of Experiment Aurora data is questionable. Indeed other and completely independent aspects of the experiment lead to the same conclusion.

We refer again to Figure 7, diurnal variation of signal strength on 4 Mc/s, short paths. The diagram for equinoctial periods is based upon September, October 1954, February, and March 1955 data. Qualitatively speaking the same diagram can be considered representative of the spring results alone; as it has been shown in "Task A - Final Report - March 1958" published by the Geophysical Institute, the signal strength diagram for February and March alone does not differ considerably from the one related to September, October 1954, February, and March 1955 data. We see in Figure 7 a noteworthy effect. The signal on E-W short path, 4 Mc/s, during winter and summer seasons is weaker than the corresponding S-N signal; while it is stronger during the spring equinoctial period.

Together with this information other data that permit a better insight of the situation are available. Measurements of ionospheric absorption of extraterrestrial radio waves on 30 Mc/s were made with a rotating antenna at College during the spring equinoctial period of 1955 (see Little and Leinbach - 1958). This experiment explored the absorption in a ring shaped area centered at College and limited by radii of approximately 200 and 500 kilometers, which is the same region examined during Experiment Aurora. During March 1955 twenty-two major events were observed. Quiet day curves of extraterrestrial signals were prepared for the four quadrants: NW, NE, SE, and SW. The absorption for the disturbed periods were then scaled against the four quiet day curves. The median of the absorption for the twenty-two events in March 1955 compared to the same absorption in the NE quadrant is illustrated in Figure 9.

From the data displayed in Figure 7 and 9 it is possible to deduce that while for the Experiment Aurora the ratio

$$\frac{(\text{signal strength on East to College, short path, 4 Mc/s})}{(\text{signal strength on South to College, short path, 4 Mc/s})}$$

increases about two times with respect to quiet periods, for the experiment of the rotating antenna the ratio relative to disturbed periods

$$\frac{(\text{absorption in the region East of College, 30 Mc/s})}{(\text{absorption in the region South of College, 30 Mc/s})}$$

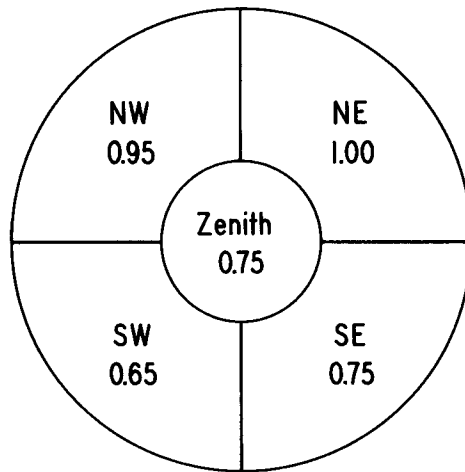


Fig. 9. Median Values of the Ratio of Absorption to that in the NE Direction for the Zenith, and NW, SE, and SW Directions Based on Twenty-two Events in March, 1955.

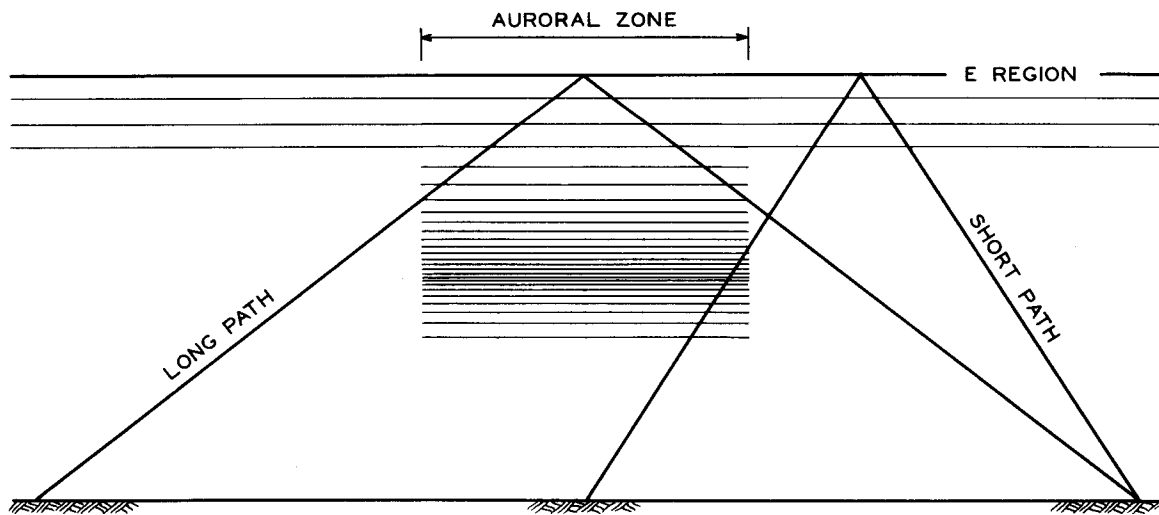


Fig. 10. Long Paths, Short Paths and the Auroral Zone.

increases 15% over the same ratio for quiet periods. Note that we compare signal strengths to absorptions.

This antinomy between Experiment Aurora and the experiment of the rotating antenna, together with the internal antinomy of Experiment Aurora on differently oriented paths can be explained along the same lines we have followed under A); that is by invoking a change in ν . The difference between the antinomy examined under A) and the present antinomy is: in A) we were comparing a situation in winter and in summer (quiet periods) with a situation in equinoctial (disturbed) periods; in B) we compare a path partially developed in the auroral zone with a path fully developed in the auroral zone. In one case we are correlating over time, in the other case we are correlating over space, but the problem is the same.

C) Further support to the idea of an increase of the collision frequency in connection with disturbances in the auroral ionosphere comes from the fact that the diurnal variation of absorption on 4 Mc/s is positive for long paths and negative for short paths. The sketch in Figure 10 depicts our interpretation of this third antinomy.

Before we close our comments on the results of Experiment Aurora it is worth pointing out that partial data obtained in 1949 - 1950 seem to present a general trend that is in agreement with the trends in Figures 7 and 8, and discussed above; therefore, we do not doubt on the reliability of our deductions.

D) If the conclusion drawn under A) and B) is true, we should expect to find a displacement in the discontinuity that affects midday f_{\min} plots at College, Alaska when comparing quiet and disturbed period data. This is indeed the case; a typical example is shown in Figure 11. Therefore it follows from the f_{\min} plots that ν increases in consequence of a disturbance; the amount of the increase is approximately from 3×10^6 to $6 \times 10^6 \text{ sec}^{-1}$. The order of magnitude of this increase is consistent with the variation detected through Experiment Aurora.

E) A second indication about the change in ν during periods of magnetic activity - which are normally related to auroral activity - is furnished by f_{\min} plots. We make reference to f_{\min} plots at College on October 13 and October 18, 1957 (see Figure 12). The hours around noon on October 13 are characterized by a K index equal to 3, the meridian stationary point of absorption is recorded exactly at 1200; the hours around noon on October 18 are characterized by a K index equal to 1, the maximum of absorption is recorded at 1215. Now, according to Mitra and Jones (1954), the relaxation time (or lag between solar transit and maximum or minimum of absorption) obeys the law

$$\tau = \frac{1}{2 \alpha N_{\text{noon}}}$$

where τ = relaxation time and α = recombination coefficient.

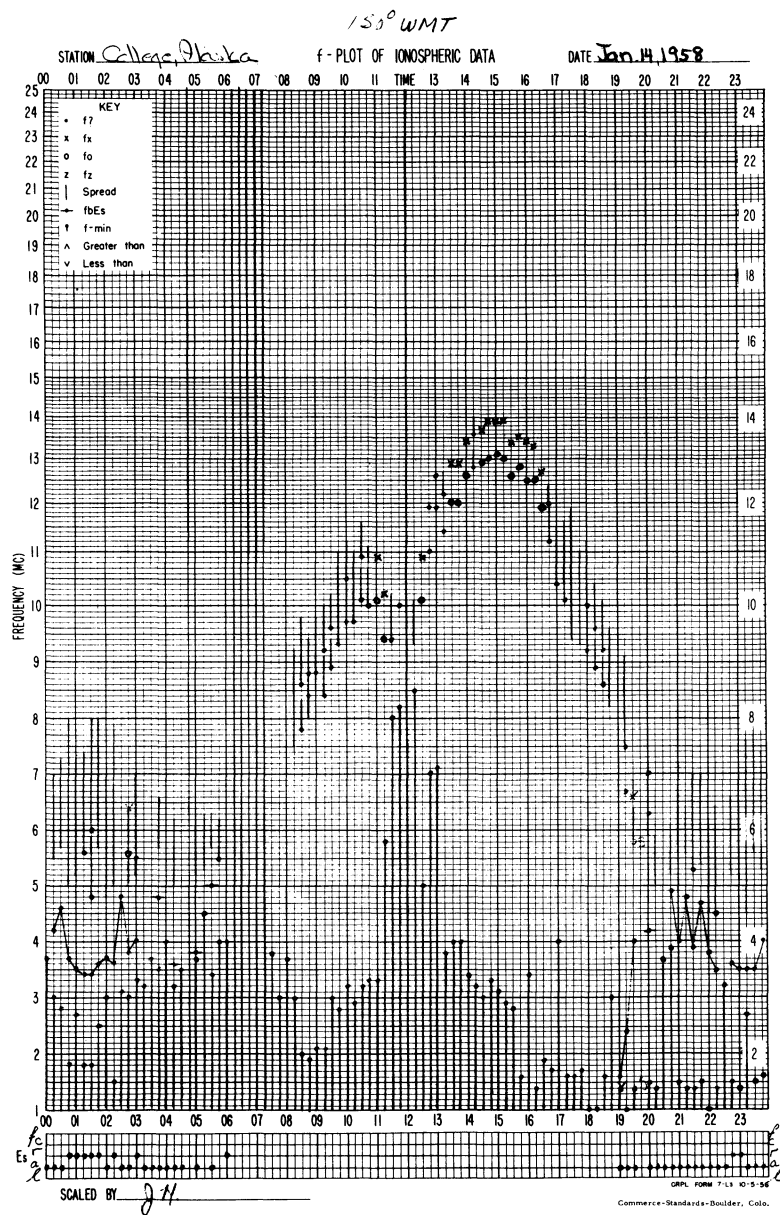


Fig. 11. Typical F-Plots for Disturbed Day.

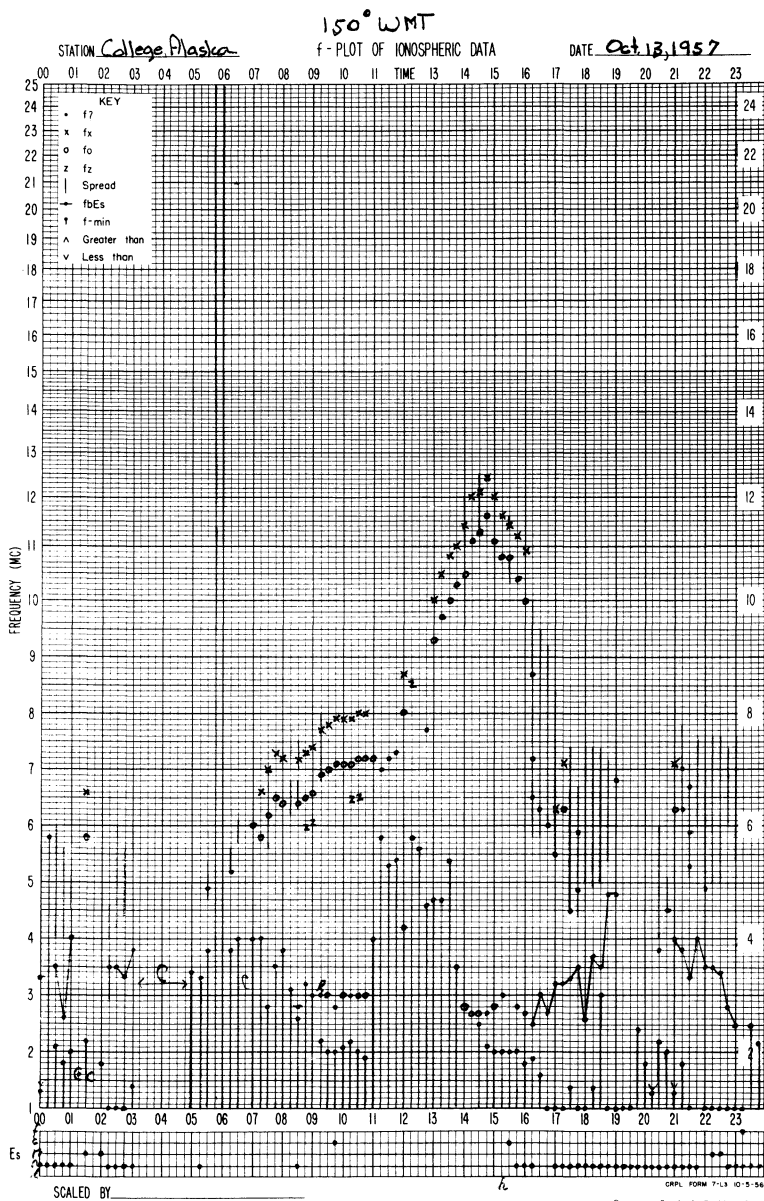
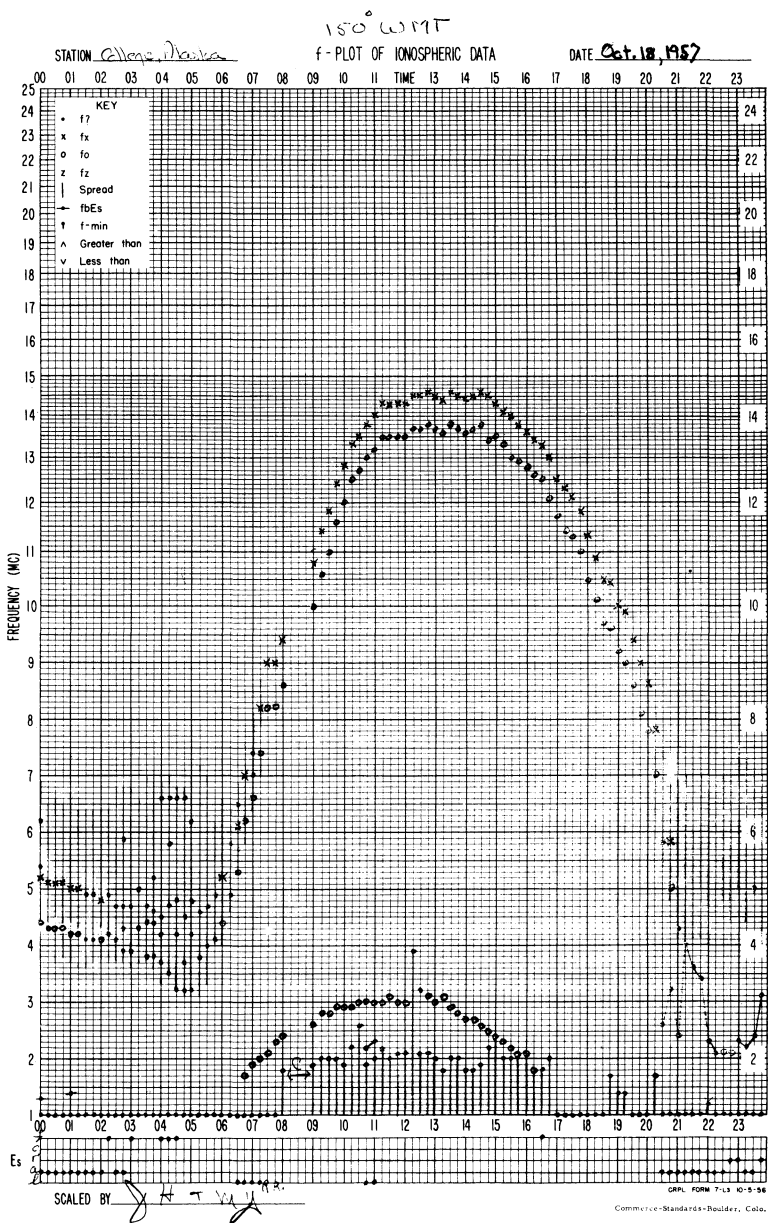


Fig. 12.



F-Plots.

Let us suppose that N_{noon} produced by photoionization is about the same on October 13 and on October 18. We emphasize here that the present utilization of the data is possible because of the evident, strong solar control of the absorption, in the absence of perturbations. We know that α and ν are both decreasing with height in the D region; we infer that ν must have been changed, being larger on October 13 than on October 18. This deduction, under E), is only of indicative character; it concludes our considerations related to f_{min} plots.

9 - CONCLUSION NUMBER TWO

Experiment Aurora data and f_{min} plots obtained in Alaska lead to the conclusion that during spring and fall an increase of effective collision frequency takes place at auroral latitudes; most likely due to auroral activity.

It should be emphasized that all our considerations are necessarily limited to diurnal absorption when a) solar control is preponderant, and b) eventual auroral disturbances characterized by intense and irregular variation of N are just overcome. Then simultaneity between auroral disturbances and the increase of ν cannot be checked, but rather consecutiveness between the two facts. Other techniques of investigation - for example radio wave interaction - should be used if more general and complete information on the subject is desired.

Nevertheless, from our results it is already possible to draw some predictions of practical interest; namely, we can state that at auroral latitudes an auroral storm could even improve communications when a specific band of frequencies is used. Curves similar to the one sketched in Figure 2 and displaced horizontally in accordance with any given change in ν will illustrate the situation; experimental data like the ones in Figure 7 indicate that relatively low absorption for frequencies between 4 to 6 Mc/s occurs under the effect of magnetic disturbances.

10 - ACKNOWLEDGEMENTS

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